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Microstructure and durability of fly ash cement grouts for micropiles

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HIGHLIGHTS

- Durability of micropiles increases when using cement containing fly ash.
- The refinement of the pore network may be the origin of that improvement.
- The impedance spectroscopy can be used to study the microsctructural evolution.
- The only limiting factor for the use of fly ash cement is the maximum w:c ratio used.
- Under the studied conditions the use of fly ash cements can be recommended for grouting micropiles.

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ABSTRACT

This paper presents a study on the possibility of using fly ash cement as grouts for micropiles. This type of special geotechnical work is commonly used for many applications. Generally, micropiles grouts are prepared using Portland cement, although the standards do not restrict the cement type to use, as long as they achieve a strength requirement. In this research, fly ash cement grouts made with w:c ratios 0.40, 0.45, 0.50 and 0.55 were studied from 2 up to 90 days of age. Their microstructure was characterized using the non-destructive impedance spectroscopy technique, electrical resistivity, and mercury intrusion porosimetry. Their durability properties have been studied by determining the water penetration under pressure, and the chloride diffusion coefficient. The compressive strength was also measured and determined, and a maximum water:cement ratio, different for each cement type was obtained. All the results were compared to those obtained for Portland cement grouts. The results obtained confirm that the performance of micropiles made using fly ash cement grouts is adequate, and as it is well know the cements with mineral admixtures provide environmental benefits, so the use of cement including fly ash will contribute to the sustainability, with similar properties to those given by OPC.

1. Introduction

In the field of geological engineering, the use of special geotechnical works has become very important. Some of the most commonly used special geotechnical works for civil engineering structures and for building foundations are piles, micropiles, soil anchors and jet grouting injections. There are great differences between those types of works and one of these differences is related to the material in which the steel reinforcement elements are embedded. In the case of the piles, concrete is usually used. However, for micropiles, soil anchors and jet grouting injections, the reinforcement elements are embedded in cement grouts, although mortars might also be used. This fact is very important, because the behavior of the cement grouts and mortars shows many differences compared to concrete. For example, in general the porosity of hardened grouts is greater than the porosity of concretes [1,2], and it could influence the durability and mechanical properties of the elements of each particular special geotechnical work. But on the other hand, a higher amount of cement might improve the durability of this type of elements. So, a different performance could be expected if the material used to protect the reinforcement steel elements is cement grout or concrete, as it is usual for the majority of civil engineering structures. Furthermore, the uncertainties can increase as a function of the cement type used, especially if it is used a sustainable cement, which incorporates some kind of active addition, instead of an ordinary Portland cement, as it is the usual practice.

Between the different types of grouted special geotechnical works, in the particular case of this research the micropiles have been studied. Micropiles are cylindrical members with diameters of under 300 mm, drilled and grouted with cement grout or mortar

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injected in one or two phases, reinforced with steel tubing and sometimes strengthened with one or several ribbed bars [3]. In Fig. 1a and b it is shown an example of micropiles use, and four different sections of a micropile, depending on the type of reinforcement employed [3–5].

Regarding the different standards about micropiles materials and implementation existing all over the world, it is important to highlight the Spanish/European Standard for micropile construction UNE-EN 14199 [4] and the US Department of Transportation, Federal Highway Administration's manual entitled Implementation manual for Micropile Design and Construction Guidelines FHWA-SA-97-070 [3]. Moreover, in Spain the Ministry of Internal Development has published a guide for designing and building micropiles in road works [5], which develops and supplements the contents of European micropiles standard [4].

Nowadays the global warming constitutes an important environmental problem, and one of the ways to solve it is reducing the CO_2 emission of the industries. In the particular case of cement industry, the use of active additions to improve their sustainability is an important field of study [6–10]. The most popular active additions are ground granulated blast-furnace slag, fly ash and silica fume. In general, these additions are wastes of other industrial processes, but their hydration reaction produces materials similar to those of clinker hydration. So, they can be reused to replace a percentage of this clinker in the cement final manufacture product.

As it has been abovementioned, one of the most popular active additions is fly ash, whose effects on the properties of cement-based materials are the object of considerable research [6,11,12]. One of the main property of this admixture is its capacity for reacting with portlandite, which is a product of the hydration of the calcium silicates of the clinker, through the pozzolanic reactions [11,13,14]. New hydrated phases are obtained as products of these reactions that improve the properties of cement-based materials. Fly ash performs very well particularly for structures in marine environments [6,15–17].

Nevertheless, in spite of this good behavior for many uses, the cements containing active additions in general, and especially fly ash, are not commonly used for preparing cement grouts for micropiles. There are not strong reasons which talk out of its use for this purpose. Moreover, regarding other special geotechnical works, the situation is very similar and only there are few studies in this field. One of these researches has been recently published and it deals with the optimization of both the w:c ratio and the binder design, by using silica fume in order to modify the viscosity [18] and to improve the service behavior of cement grouts. With respect to fly ash, there are some studies that claim the feasibility of using fly ash in structural fills, and other geotechnical applications [19,20]. In view of that, as it has been shown, up to our knowledge the performance of fly ash cements for micropiles grouts has not been studied, especially with regard to their microstructure and

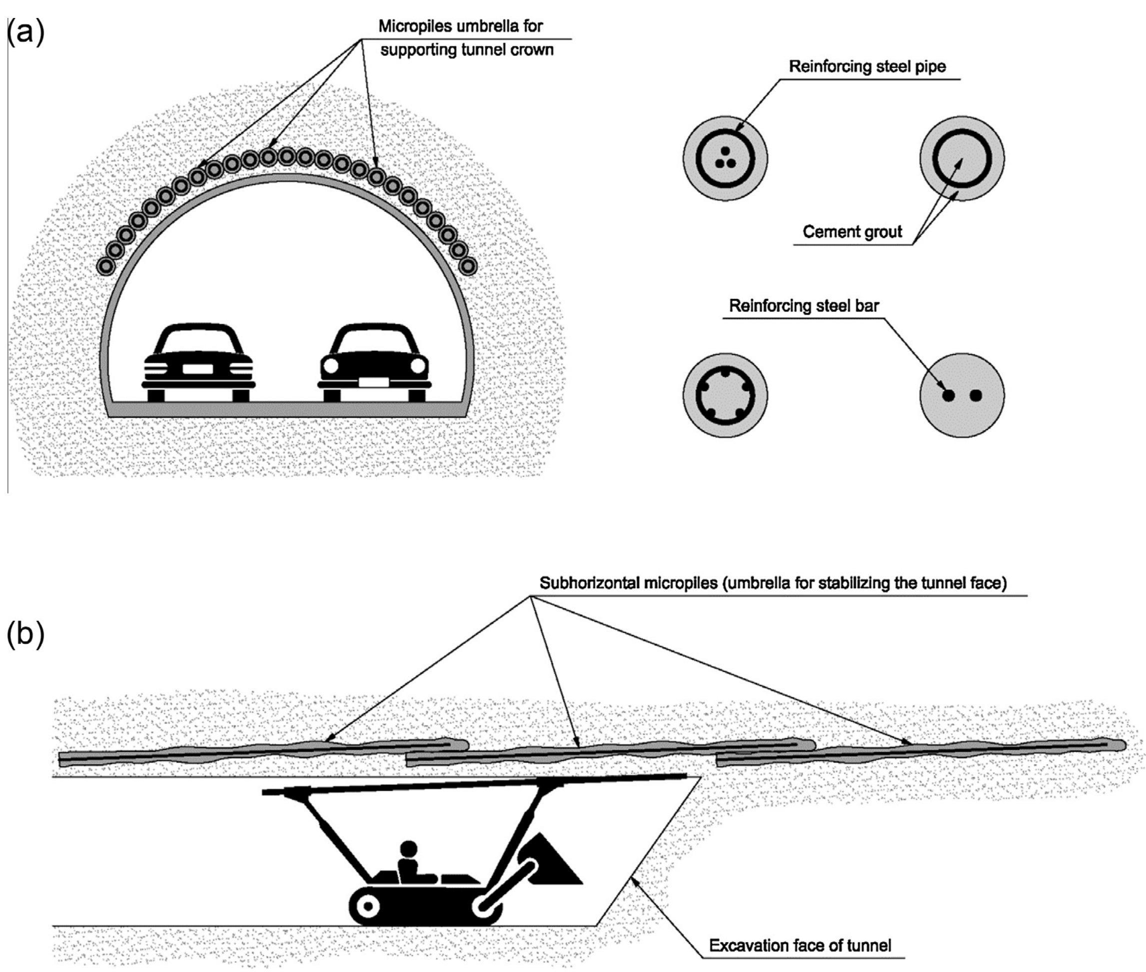

Fig. 1. (a) Schematic representation of a road tunnel cross-section whose crown is supported by an umbrella of micropiles reinforced with steel pipe (left) and different sections of a micropile, depending on the type of reinforcement employed (right). (b) Excavation process of a tunnel face stabilized using a subhorizontal micropiles umbrella [3–5].